List of topics for this laboratory:

- Nodal Analysis
- Linearity
- Superposition Theorem
- Thevenin’s Theorem

Tools and Equipments Required:

- DMM (Digital Multi Meter)
- Oscilloscope
- Breadboard
- Resistors
- AC Signal generator
- DC power supply

Information:

Nodal Analysis

Nodal analysis provides a general procedure for analyzing circuits using node voltages as the circuit variables. Choosing node voltages instead of element voltages as circuit variables is convenient and reduces the number of equations one must solve simultaneously.

In nodal Analysis, we are interested in finding the node voltages. Given a circuit with n nodes without voltage sources, the nodal analysis of the circuit involves taking the following three steps:

- Select a node as reference node. Assign voltages $v_1, v_2, v_3, \ldots, v_{n-1}$ to the remaining n-1 nodes. The voltages are referenced with respect to the reference node.
- Apply KCL to each of the n-1 non reference nodes. Use Ohm’s Law to express the branch currents in terms of node voltages.
- Solve the resulting simultaneous equations to obtain the unknown node voltages.
If the circuit has voltage sources, there are two possibilities:

- If a voltage source is connected between the reference node and a nonreference node, we simply set the voltage at the nonreference node equal to the voltage of the voltage source. In fig 1.1, for example:

\[ v_1 = 10V \]

- If the voltage source (dependent or independent) is connected between two nonreference nodes, the two nonreferenced nodes form a supernode, we apply both KVL and KCL to determine node voltages. In Figure 1.1, nodes 2 and 3 form a supernode.

We analyze a circuit with supernodes using the same three steps mentioned in the previous section except that the supernodes treated differently. We apply the KCL rule to the supernode only instead of applying it to two nodes separately. Hence, at the supernode in figure 1.1:

\[ i_1 + i_4 = i_2 + i_3 \]

or

\[ \frac{v_1 - v_2}{2} + \frac{v_1 - v_3}{4} = \frac{v_2 - 0}{8} + \frac{v_3 - 0}{6} \]
Linearity Property

Linearity is the property of an element describing a linear relationship between cause and effect. The property is a combination of both the homogeneity property and additivity property.

The homogeneity property requires that if the input (also called the excitation) is multiplied by a constant, then the output (also called the response) is multiplied by the same constant. For a resistor, for example, Ohm’s law relates the input $i$ to the output $v$,

$$v = iR$$

If the current is increased by a constant $k$, then the voltage increases correspondingly by $k$, that is,

$$k iR = kv$$

The additivity property requires that the response to a sum of inputs is the sum of the responses to each input applied separately. Using the voltage-current relationship of a resistor, if

$$v_1 = i_1 R$$
$$v_2 = i_2 R$$

then applying $(i_1 + i_2)R$ gives

$$v = (i_1 + i_2)R = i_1 R + i_2 R = v_1 + v_2$$

In general, a circuit is linear if both additive and homogeneous. A linear circuit consists of only linear elements, linear dependent sources, and independent sources.

Superposition

The superposition principle states that the voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (currents through) that element due to each independent source acting alone.

To apply the superposition principle, we must keep two things in mind:

- We consider one independent source at a time while all other independent sources are turned off. This implies that we replace every voltage source by 0 V (or a short circuit), and every current source by 0 A (or open circuit). This way we obtain a simpler and more manageable circuit.

- Dependent sources are left intact because they are controlled by circuit variables.

Steps to apply Superposition Principle:
1. Turn off all independent sources except one source. Find the output (voltage or current) due to that active source using nodal or mesh analysis.

2. Repeat step 1 for each of the other independent sources.

3. Find the total contribution by adding algebraically all the contributions due to the independent sources.

**Thevenin’s Theorem**

It often occurs in practice that a particular element in a circuit is variable (usually called the load) while other elements are fixed. Each time the variable element is changed, the entire circuit has to be analyzed all over again. To avoid this problem, Thevenin’s theorem provides a technique by which the fixed part of the circuit is replaced by an equivalent circuit.

According to Thevenin’s theorem, the linear circuit in Figure 1.2(a) can be replaced by that in Figure 1.2(b). (The load in Figure 1.2 may be a single resistor or another circuit). The circuit to the left of the terminals a-b in Figure 1.2(b) is known Thevenin’s equivalent circuit.

Thevenin’s theorem states that a linear two terminal circuit can be replaced by an equivalent circuit consisting of a voltage source \(V_{th}\) in series with a resistor \(R_{th}\) where \(V_{th}\) is the open-circuit voltage at the terminals and \(R_{th}\) is the input or equivalent at the terminals when the independent sources are turned off.

Our major concern right now is how to find the Thevenin equivalent voltage \(V_{th}\) and resistance \(R_{th}\). To do so, suppose the two circuits in Figure 1.2 are equivalent. Two circuits are said to be equivalent if they have the same voltage-current relation at their terminals. Let us find out what will make the two circuits in Figure 1.2 equivalent. If the terminals a-b are made open-circuited (by removing the load), no current flows, so that the open-circuit voltage across the terminals a-b in Figure 1.2(a) must be equal to the voltage source \(V_{th}\) in
Figure 1.2(b), since the two circuits are equivalent. Thus $V_{th}$ is the open-circuit voltage across the terminals as shown in Figure 1.3(a); that is

$$V_{th} = v_{oc}$$

![Diagram showing two-terminal circuit](image)

Figure 1.3(a)

Again, with the load disconnected and terminals a-b open-circuited, we turn off all independent sources. The input resistance (or equivalent resistance) of the dead circuit at the terminals a-b in Figure 1.2(a) must be equal to $R_{th}$ in Figure 1.2(b) because the two circuits are equivalent. Thus, $R_{th}$ is the input resistance at the terminals when the independent sources are turned off in Figure 1.3(b) that is,

$$R_{th} = R_{in}$$

To apply this idea in finding the Thevenin resistance $R_{th}$, we need to consider two cases.

- If the network has no dependent sources, we turn off all independent sources. $R_{th}$ is the input resistance of the network looking between terminals a and b, as shown in Figure 1.3(b).

- If the network has dependent sources, we turn off all independent sources. As with superposition, dependent sources are not to be turned off because they are controlled by circuit variables. We apply a voltage source $v_0$ at terminals a and b and determine the resulting current $i_0$. Then $R_{th} = \frac{v_0}{i_0}$, as shown in Figure 1.4(a). Alternatively, we may insert a current source $i_0$ at terminals a-b as shown in Figure 1.4(b) and find the terminal voltage $v_0$. Again $R_{th} = \frac{v_0}{i_0}$. Either of the two approaches will give the same result. In either approach we may assume any value of $v_0$ and $i_0$. 

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Preliminary Work:

1) Do the preliminary work in procedure part 1.
2) Do the preliminary work in procedure part 3.
3) Do the preliminary work in procedure part 5.
Procedure:

1) Calculate the node voltages \( V_x \) and \( V_y \) and the currents on \( R_1, R_2, R_3, R_4, R_5 \) in the network in figure 1.5 (Preliminary work). And then construct the network in figure 1.5, measure the node voltages \( V_x \) and \( V_y \) and the currents on \( R_1, R_2, R_3, R_4, R_5 \). Then write them on table 1.1.

![Figure 1.5](image)

<table>
<thead>
<tr>
<th>Calculated values</th>
<th>Measured values</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_x )</td>
<td></td>
</tr>
<tr>
<td>( V_y )</td>
<td></td>
</tr>
<tr>
<td>( I_1 )</td>
<td></td>
</tr>
<tr>
<td>( I_2 )</td>
<td></td>
</tr>
<tr>
<td>( I_3 )</td>
<td></td>
</tr>
<tr>
<td>( I_4 )</td>
<td></td>
</tr>
<tr>
<td>( I_5 )</td>
<td></td>
</tr>
</tbody>
</table>

Table 1.1

2) Construct the network in figure in 1.6, measure the currents through \( R_1, R_2, R_3 \) then write them on table 1.2. Then measure the currents again for \( V_1 = 8V \) and \( V_2 = 12V \). Write the new values on table 1.2. Is the circuit linear or not? If linear tell me, why?
3) Calculate the current passing through $R_3$ in figure 1.7 with superposition method and write the value on table 1.3 (Preliminary work).

4) Construct the circuit in figure 1.7 and measure the current passing through $R_3$. Write the value on table 1.3.
\( I_{R3} \) calculated \( I_{R3} \) measured

Table 1.3

5) In figure 1.8, \( R_4 \) is load, calculate the thevenin resistance \( (R_{th}) \) and thevenin voltage \( (V_{th}) \) then find the current passing through \( R_4 \) with thevenin theorem and write the value on table 1.4 (Preliminary work).

6) Construct the circuit in figure 1.8 and measure the current passing through \( R_4 \). Write the value on table 1.4.

\[ \begin{array}{c}
\text{2} \\
\text{1.8kΩ} \\
\text{12V} \\
\text{1kΩ} \\
\end{array} \]

\[ \begin{array}{c}
\text{R1} \\
\text{R2} \\
\text{R3} \\
\text{R4} \\
\end{array} \]

\( I_{R4} \) calculated \( I_{R4} \) measured \( (R_{th}) \) \( (V_{th}) \)

Table 1.4

7) You have a circuit, which made only with resistances. Can we apply superposition theorem to power relation \( (V = I^2R) \)? If no, why?

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